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A DEA Approach to Evaluating Characteristics of J-League Players in terms of Time played and Player Similarity

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In this paper, J-league player performance was evaluated using data envelopment analysis (DEA) models to identify player characteristics from the standpoints of time played and player similarity. For this purpose, the concepts of scale efficiency and super efficiency were introduced to this study. Time played was used as the input and data from ten basic plays or actions such as goals, passes, dribbles and fouls, were used as the outputs. The performance of J-league field players was analyzed according to player position using data from the 2013 season based on the CCR (Charnes-Cooper-Rhodes) and BCC (Banker-Charnes-Cooper) models. Characteristics were discussed in reference not only to efficiency scores, but also scale efficiency and super efficiency scores. The suitability of player time on pitch was identified by scale efficiency with estimation of returns to scale. Efficient players were differentiated by super efficiency scores, and the relationship between efficient players was quantified with regard to the characteristics of plays in the position.

Keywords: BCC, DEA, Evaluation, Scale Efficiency, Super Efficiency

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1. Introduction

Data envelopment analysis (DEA) is a method of obtaining a relative evaluation of the efficiency of study subjects utilizing the ratio of outputs to inputs. This method is often used in analyzing the efficiency of business organizations (e.g. Copper et al., 2007). It is also used to evaluate the efficiency of teams and players in baseball and soccer. When applied to sports teams, DEA can evaluate efficiency in terms of number of wins against total annual salary of players, in other words, the efficiency of winning with lower total annual salaries (e.g. Lewin et al., 2013). Applied to players, DEA can evaluate efficiency according to position in terms of successful goals, assists, passes, and tackles against time played (Tiedemann et al., 2011), or can rank players in terms of games played and successful goals (Santin, 2014).

Hirotsu et al. (2012) focused on the characteristics rather than the rank of each soccer player. They used annual data from the J-League Division 1 (J1) in 2008, used time played as an input, and used successful basic plays such as goals, passes, and dribbles as outputs for analysis applying the Charnes-Cooper-Rhodes (CCR) model (e.g. Copper et al., 2007), the most basic DEA model, to extract the characteristics of each player and indicate target values for improvement. Their study was significant for its attempt to extract the characteristics of according to player using DEA to evaluate the frequency of basic plays in combination with multiple items. In other words, when evaluating each player based on frequency of basic plays, not only did they separately evaluate the frequency of successful goals and crosses, but also the combined frequency of both successful goals and crosses to identify the characteristics of each player for evaluation based on a 0 to 1 index of "efficiency." DEA was also applied to evaluate player similarity, which also includes frequency of basic plays between players.

In general, team "efficiency" is calculated as a function of cost; that is, the number of wins per year against total annual player salaries. Although the analysis conducted by Hirotsu et al. (2012) used the term "efficiency" as defined by DEA, they simply focused on the frequency of successful individual goals and passes during a game by defining success as a function of the higher number of goals or passes. In other words, considering basic plays in a comprehensive manner, a player whose efficiency score is "1" has a specific characteristic of frequency that cannot be seen in other players.

Hirotsu et al. (2012) evaluated player characteristics utilizing the CCR model. However, the CCR model is based on constant returns to scale. Evaluation requires that the ratio of frequency of plays to time played is constant regardless of the actual time played. If the time played doubles, the frequency of basic plays doubles. This CCR model is problematic due to the fact that it obtains efficiency scores based on time played without considering the difference of impact caused by the length of time played between players with longer and less time played. Hirotsu et al. (2012) also found a relationship between efficient and inefficient players utilizing the CCR model. However, analysis utilizing CCR model alone can neither quantify the difference in characteristics among players with an efficiency score of "1," nor find similarity in characteristics among efficient players. Therefore, the CCR model has limitations as an analytical method for the evaluation of player characteristics.

To address these issues, we should employ both the Banker-Charnes-Cooper (BCC) model and the concept of super efficiency for analysis. BCC models variable returns to scale, which can evaluate player efficiency scores and scale efficiency considering player time on pitch. This makes it possible to analyze data that fully considers the characteristics of each player from the standpoint of whether the player should play more or less in the season, and determine suitable time played for each player. This is a completely different evaluation based on "scale efficiency".

The concept of super efficiency allows us to observe the differences in characteristics of players with efficiency scores of "1," which allows us to perceive similarity in characteristics among efficient players. The concept of super efficiency allows an efficiency score greater than 1, which Santin (2014) also adopted. The implementation of the concept of super efficiency makes it possible to efficiently quantify the similarity of efficient players' characteristics and to evaluate the characteristics of a player based on a combination of other players, which could be useful in player recruitment.

This study was carried out to analyze the performance of J1 players in terms of appropriate time played, difference and similarity in player characteristics based on the study by Hirotsu et al. (2012) adopting the BCC model and the concept of super efficiency, and to compare evaluation utilizing the CCR model with evaluation utilizing the BCC model and the concept of super efficiency.

2. Method

2.1. Data

For analysis in this study, we first selected data in accordance with the study by Hirotsu et al. (2012). We selected time played as an input, and frequency of ten major plays such as goals and passes as outputs as shown below.

Input (1 item): Time played
Outputs (10 items): Number of goals, assists, passes, crosses, dribbles, tackles, intercepts, clearances, blocks, and fouls

(Note)
Passes: Number of passes to a team player
Crosses: Number of crosses to a team player
Dribbles: Number of successful dribbles
Fouls: Difference from the maximum number of fouls after conversion with time played (Evaluated as a grade)

Although fouls were used as an output, it is of greater advantage to have a lower number different from other outputs. Therefore, we converted data for evaluation. Hirotsu et al. (2012) set the base number of fouls per unit time at 78 times/ 1414 minutes (0.05512 times/ min.) utilizing the data of S. HIRAYAMA who committed the maximum number of fouls in 2008. This study set the base number per unit time at 53 times/ 1287 minutes (0.04118 times/ min.) by WELLINGTON from 2013 data.

We acquired 2013 J1 data aggregated by Data Stadium Inc. and evaluated the above-mentioned 11 input and outputs for players who played more than 900 minutes according to their registered position.

Subjects were 238 players; namely, 57 forwards (FW), 95 mid fielders (MF), and 86 defenders (DF). A summary of evaluation item statistics according to their position is shown in **Table 1**.

FW goals, assists, passes, crosses, and dribbles in the shaded area of **Table 1** are in order of frequency, as shown in **Table 2**. This shows FW characteristics. For example, Y. OKUBO ranked top in number of goals, and RENATO was top in number of assists and crosses, which reveal characteristics. Utilizing DEA, we can also identify player characteristics for multiple items. DEA obtains better analytical results than those acquired from frequency data.

2.2. Models

As for the DEA model, we will first explain the CCR model, followed by the BBC model and the concept of super efficiency.

2.2.1. CCR Model

DEA allows a relative evaluation employing the ratio of inputs and outputs. If we define "goal rate" as the ratio of "goals/ time played," the goal rate equals the ratio of "time played (input)" and "goals (output)," which evaluates player efficiency. Multiple items can be employed as inputs and outputs in DEA. If "passes" are added as outputs, the ratio is defined as "time played (input)" and "u_1×goals+u_2×passes" (output). The variables u_1 and u_2 express the weight

Table 1 Summary statistics

Position	No, of players		Time	Goals	Asists	Passes	Crosses	Dribbles	Tackles	Inter-ceptions	Clears	Blocks	Fouls	(Foul Points)
FW	57	Average	1906.4	7.7	2.9	435.7	7.2	21.8	19.0	3.1	20.2	22.5	35.6	(42.9)
		SD	636.3	6.0	2.3	192.3	6.9	18.2	11.6	2.4	13.5	8.8	15.5	(23.9)
		Max	2969	26	11	866	29	81	67	13	56	42	79	(91.6)
		Min	937	0	0	162	0	1	4	0	0	5	15	(0.00)
MF	95	Average	2142.3	2.3	3.0	916.8	9.5	15.1	39.6	9.1	34.4	42.8	28.2	(60.0)
		SD	686.7	3.0	2.6	487.6	9.0	17.3	23.2	5.9	20.1	18.2	14.5	(22.4)
		Max	3060	21	12	2910	44	105	130	24	128	83	65	(113.3)
		Min	902	0	0	228	0	0	7	0	4	8	5	(15.8)
DF	86	Average	2148.0	1.5	1.1	858.8	7.4	7.1	42.1	8.2	81.3	48.7	25.7	(62.8)
		SD	674.4	1.6	1.5	413.2	11.5	10.7	19.3	6.0	33.4	18.0	11.6	(23.9)
		Max	3060	9	8	2565	58	64	96	33	164	90	67	(109.9)
		Min	910	0	0	187	0	0	10	0	10	17	5	(18.5)

Table 2 Top and bottom players in terms of goals, assists, passes, crosses and dribbles for FW

Player	Goals	Player	Asists	Player	Passes	Player	Crosses	Player	Dribbles
Y.OKUBO**	26	RENATO*	11	RENATO*	866	RENATO*	29	RENATO*	81
K.KAWAMATA	23	J.TANAKA	11	K.TAMADA	857	Choi Jung-Han	26	JUNINHO	63
Y.TOYODA	20	KENNEDY	7	Y.OKUBO**	842	JUNINHO	23	CHO Young Cheol	61
Y.OSAKO**	19	M.SAITO*	6	LUCAS Severino	811	T.TAKAGI	22	Choi Jung-Han	61
M.KUDO	19	…	…	CHO Young Cheol	791	M.SAITO*	20	M.SAITO*	57
…	…	…	…	…	…	…	…	…	…
…	…	…	…	…	…	R.MAEDA	1	…	…
K.YANO	1	H.KANAZONO	0	A.YANAGISAWA	195	S.ITO	1	Y.MORISHIMA	5
Choi Jung-Han	1	WELLINGTON	0	QUIRINO	185	H.KANAZONO	0	HUGO	5
A.KAWAMOTO	1	A.KAWAMOTO	0	Radončić	174	HUGO	0	K.TAKETOMI	4
M.MATSUHASHI	0	HUGO	0	BARE	171	T.YAZIMA	0	H.KANAZONO	2
GILSINHO	0	K.TAKETOMI	0	T.YAZIMA	162	A.YANAGISAWA	0	A.YANAGISAWA	1

Remarks) * Recognized as outstanding players in 2013
** Recognized as the best eleven in 2013

of goals and passes. If an evaluator determines the weight u_1 as 10 and u_2 to be 1 considering the goal is ten times as important as the pass, the evaluation scale is influenced by evaluator bias. In order to avoid evaluator influence on DEA, we must select u_1 and u_2 values to obtain the maximum ratio; in other words, the highest evaluation. In such case, there is no deviation by evaluator, and all players can be evaluated by their most advantageous weight, which is fair for everyone. DEA sets a player with the maximum ratio as the standard (1) to evaluate each player with the efficiency score of 0 to 1. If a player cannot achieve an efficiency score of 1 even after evaluation with the most advantageous weight, the player is inferior to the players that had an efficiency score of 1. The model that evaluates subjects with such a ratio is CCR. Hirotsu et al. (2012) also evaluated players utilizing the CCR model.

2.2.2. BCC Model and Scale Efficiency

The above-mentioned CCR model was developed into the BCC model. We replace time played (input) with v_1×time played+v_0, and the v_1 and v_0 values were selected to obtain the maximum ratio for each player. The greater the increase in the number of variables, the greater the increase in the level of flexibility. This can convert to the multi-input-multi-output formula shown below. When the number of inputs is m and the number of outputs is s, data (x_{ij_o}) regarding input i (=1,2,…,m) of a subject player (j_o) was multiplied by weight (v_i). Adding v_0 to the result yields virtual input $\sum_{i=1}^{m} v_i x_{ij_o} + v_0$. The data (y_{rj_o}) regarding the output r (=1,2,…,s) of a subject player (j_o) was multiplied by weight (u_r). It yields virtual output $\sum_{r=1}^{s} u_r y_{rj_o}$

$$\text{Ratio}=\frac{\text{Virtual output}}{\text{Virtual input}}=\frac{\sum_{r=1}^{s} u_r y_{rj_o}}{\sum_{i=1}^{m} v_i x_{ij_o}+v_0} \qquad (1)$$

This is the ratio in the BCC model. The BCC model determines the suitable v_0, v_i, and u_r of subject players to maximize (1) under non-negative conditions, and calculates efficiency scores. In the present study, we use one input and ten outputs; therefore, m=1 and s=10.

The significance of adding the new variable v_0 can be explained in a case of one input and output utilizing "v_1× time played + v_0" as input and "u_1× number of goals" as output. **Figure 1** shows the relationship between time played and goals of 57 FW in J1 during 2013. Point D in **Figure 1** shows K. KAWAMATA (time played: 2503 min., number of goals: 23), and Point C shows G. OMAE (time played: 1207 min., number of goals: 7).

We compared CCR and BCC model ratios. The CCR model does not consider the variable v_0 (i.e. v_0=0). When there is one input and one output (m=1,s=10), formula (1) is described as shown below:

$$\text{Ratio} = \frac{u_1 y_{1j_o}}{v_1 x_{1j_o}} \qquad (2)$$

In this case, the player with the maximum goal percentage (goals/ time played) is K. KAWAMATA, who is shown as Point D, and the value equals the inclination of a straight line obtained by connecting the origin and Point D in **Figure 1**. If we set the ratio acquired by formula (2) at 1, the formula can be described as $1 = \frac{u_1 y_{1j_o}}{v_1 x_{1j_o}}$ which is equals $y_{1j_o} = \frac{v_1}{u_1} x_{1j_o}$.

If we set the ratio of K. KAWAMATA as the standard value, as shown above, v_1/u_1 equals 23/2503, and 0.009189. This means that the straight line running through the origin with 0.009189 inclination becomes the CCR efficient frontier with the maximum goal percentage. At the point on this straight line, the ratio shown in formula (2) is 1, which means the efficiency value is 1.

Whereas, in the BCC model, we use the variable v_0. When we set formula (1) as equal to 1 with one input and one output, the formula is described as $1 = \frac{u_1 y_{1j_o}}{v_1 x_{1j_o} + v_0}$, which becomes $y_{1j_o} = \frac{v_1}{u_1} x_{1j_o} + \frac{v_0}{u_1}$.

In this case, the ratio of points on the straight line that does not pass through the original position (0,

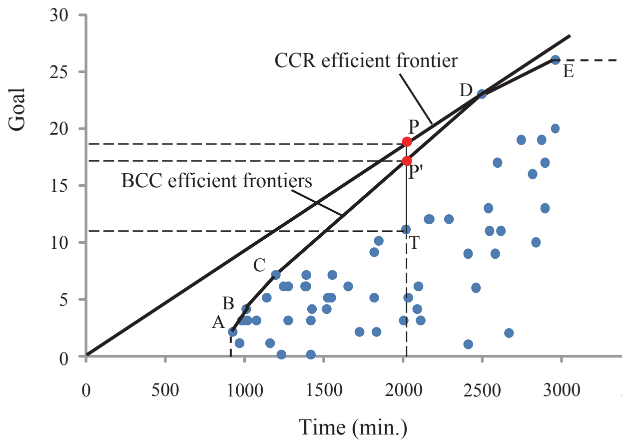

Figure 1 CCR efficient frontier and BCC efficient frontiers

0) becomes 1. For example, in **Figure 1**, the ratio of points on the straight line that passes through Points C and D becomes 1. The inclination of the straight line is v_1/u_1=(23-7)/(2503-1207)=0.01235, and the interception is v_0/u_1=-7.901. If we consider the straight line that passes through Points A and B, the straight line that passes through Points B and C, and the straight line that passes through Points D and E similarly, the points that make formula (1) equal to 1 are on a polyline that passes through Point A, B, C, D, and E that covers all players shown in **Figure 1**; and that line forms the BCC efficient frontier. In the case of multi-input-multi-output, a boundary surface that covers all players forms the BCC efficient frontier although it cannot be shown in a figure here.

For example, Point T, which does not exist on the BCC efficient frontier line, describes J. TANAKA (time played: 2022 min., number of goals: 11). The 2022 min. point of time played on the CCR efficiency frontier line is on the straight line that passes through the origin (0, 0) with a 0.009189 inclination, and shows 18.58 (=0.009189×2022) as the number of goals. This should be the target value for improvement (Point P) for J. TANAKA in the CCR model. The point on the BCC efficiency frontier line is equivalent to 17.06 (=0.01235×2022–7.901) goals, and this should be the target value for improvement (reference point P') for J. TANAKA in BCC model. For J. TANAKA who achieved 11 goals, 18.58 is the target value in the CCR model, and 17.06 in the BCC model; and the ratios with the actual goals are 11/ 18.58 (=0.592) (CCR efficiency score) and 11/ 17.06 (=0.645) (BCC efficiency score). In the CCR model, only Point D forms the efficient frontier while in the BCC model not only Point T, but also Points C and D, whose time played are close to Point T, become frontiers for the target value for improvement. Furthermore, Points B and E, whose time played are not close to Point T, are not associated with the target value for improvement. Based on this concept of models, the target value for improvement in BCC model tends to be set lower than in the CCR mode; and the efficiency score in the BCC model tends to be greater than that in the CCR model. (This method of calculation is thought to focus more on output than input because the efficiency scores are calculated from the standpoint of increasing output under the same period of time played, and called "output-oriented".)

The multi-input-multi-output (output-oriented) BCC model, which generalizes the above-mentioned one-input-one-output model, is formulated as described below (e.g. Cooper et al., 2007). For an output-oriented case, formula (3) shown below is made by replacing the denominator and numerator in formula (1).

$$\frac{\sum_{i=1}^{m} v_i x_{ij_o} + v_0}{\sum_{r=1}^{s} u_r y_{rj_o}} \tag{3}$$

And formula (3) is minimized in a constraint formula as a fractional programming problem, as shown below.

$$\frac{\sum_{i=1}^{m} v_i x_{ij} + v_0}{\sum_{r=1}^{s} u_r y_{rj}} \geq 1 \quad (j=1,\dots,n) \tag{4}$$

$$u_r \geq 0 \quad (r=1,\dots,s) \tag{5}$$

$$v_i \geq 0 \quad (i=1,\dots,m) \tag{6}$$

The reciprocal of the obtained minimum value is the efficiency score of player j_o. (There is no sign restriction such as in (5) and (6) for variable v_0). In this study, n is set for each position: 57 for FW, 95 for MF, and 86 for DF.

In the actual calculations, a fractional programming problem is replaced with a linear programming problem by standardizing the denominator of formula (3) as 1, and obtains a solution for each player j_o (j_o = 1, 2,…,n) as a minimization problem. The calculation provides the efficiency score and the variables for each player. Players with an efficiency score of 1 are thought to be BCC efficient, and characterized by frequency of plays. (Strictly speaking, players whose efficiency score is 1 and 0 for all variables called slacks are BBC efficient. In this study, all players whose efficiency score is 1 are BBC efficient.) Players who are inefficient can be compared with players who have better characteristics.

Scale efficiency can be calculated by the formula shown below (e.g. Copper et al., 2007).

Scale efficiency
= CCR efficiency score/ BCC efficiency score

When both CCR and BCC efficiency scores are 1, scale efficiency also becomes 1, which shows that players perform in a suitable scale. When scale efficiency becomes less than 1, the scale may not be suitable. Although we do not describe this in detail here, according to v_0 we can determine the returns to scale that will be described later.

2.2.3. Super Efficiency

The concept of super efficiency can be formulated by removing the constraint formula regarding the subject of evaluation for fractional programming problems in both the CCR and BCC models. In order to acquire the super efficiency score of player j_o, it is necessary to replace the range of j in formula (4) with "j=2,…, n" (j_o=1), "j=1, 2,… j_o-1, j_o+1, …, n" (2≦j_o≦n-1), and "j=1,…, n-1" (j_o=n), which means removing the constraint formula regarding j_o and solving the fractional programming problem. This removes the constraint formula that limits the efficiency score of player j_o to 1 or lower, and allows it to be greater than 1. The concept of super efficiency calls for calculation of the degree to which each efficient player differs from the efficient frontier that is formulated by other players. The greater the player's distance from the efficient frontier, the higher the player's super efficiency score becomes; and this determines that the player has more distinctive characteristics compared with other players.

2.3. Parameters

DEA analysis provides useful indices for player evaluation, not only efficiency, scale efficiency, and super efficiency, but also returns to scale, reference set, reference frequency, and lambda value. We call these parameters.

An explanation of returns to scale follows. Increasing the scale to increase the efficiency score is defined as increasing returns to scale. Decreasing the scale is defined as decreasing returns to scale. Maintaining the scale is defined as the constant returns to scale (e.g. Cooper et al., 2007). In the analysis in this study, the scale is associated with time played, which suggests whether individual time played is appropriate from the standpoint of utilizing the characteristics of each player. Therefore, the returns to scale is considered a factor in the evaluation of players.

An explanation of reference set and reference frequency follows. An inefficient player has a group of efficient players, which is characterized by greater frequency of plays, located to the direction in which the inefficient player's frequency of plays is increased. This group of efficient players is called a reference set. The greater the degree to which an efficient player is included in the reference set of an inefficient player, the more that specific efficient player becomes a target of the inefficient player in terms of the frequency of plays. The frequency is called the reference frequency. A player with a high reference frequency is a player with distinctive comprehensive characteristics. A player with low reference frequency is a player who is not considered to be a target for an inefficient player, which suggests that such a player also has a peculiar or unique play style. Therefore, reference set and reference frequency serve as indices that identify differences in the characteristics of efficient players.

Lambda value is a parameter that quantifies the relationship between players. Characteristics of efficient players and similarity in characteristics between players can be quantified by comparison with a virtual player with inputs and outputs obtained by multiplying appropriate coefficients (lambda values) by the inputs and outputs of a group of players in a reference set. Under advantageous weights of players such as v_i and u_r, frequency of play for each player is evaluated in comparison with the virtual player. Under the concept of super efficiency, an efficient player is superior to the virtual player formulated by a group of other efficient players under advantageous weights, while an inefficient player is inferior to this virtual player. Interpretation of lambda value is described in Section 4 with specific results.

2.4. Statistical Analysis

Efficiency, scale efficiency, super efficiency, and parameters were calculated using DEA calculation software, DEA-Solver-PRO (Cooper et al., 2007) manufactured by SEITECH. Co., Ltd. Results for each player were provided for comparison in both CCR and BCC models. Although Hirotsu et al. (2012) examined the characteristics of efficient players utilizing reference frequency, we adopted the concept of super efficiency which differs from the reference frequency in this study to quantify the characteristics of efficient players and similarity between players. We then examined the correlation between reference frequency and super efficiency scores utilizing the Pearson product-moment correlation coefficient as an index to clarify the characteristics of efficient players.

3. Results

3.1. Efficiency and Scale Efficiency

We classified players by position, and applied formulas (3) to (6) utilizing the eleven inputs and outputs in accordance with the method described in Section 2. **Tables 3-1** to **3-3** show the CCR and BCC efficiency scores of each player. **Table 3-1** shows the results of the 57 FWs. Twenty-five players in the CCR model and 38 players in the BCC model were evaluated as efficient. As was mentioned in 2. 2. 2, efficiency scores are evaluated in an approximate manner in the BCC model. Therefore, 13 players were evaluated as efficient in the BCC model, but as inefficient in the CCR model. BCC efficiency scores of all FW showed the same level or higher than the corresponding CCR efficiency scores. **Table 3-2** and **3-3** show results for MF and DF.

Table 3-1 to **3-3** also show scale efficiency results. No. 1-25 CCR efficient FW players are also BCC efficient, and their scale efficiency is 1. CCR inefficient FW players number 26 and after show the same CCR efficiency and scale efficiency scores if they were BCC efficient. Although no BCC efficient FW players have scale efficiency scores of "1," some MF and DF players, such as No. 55 (H. TAMEDA), in **Table 3-2** are extremely close to a scale efficiency score of "1" (shown as 1.000).

As a reference, among FW players shown in **Table 3-1**, individual target values for improvement in both the CCR and BCC models of BCC inefficient players are shown in **Table 4**. It is obvious that the target value for improvement is set lower than in the BCC model. For example, K. WATANABE (No.32) shows 0.952 (CCR efficiency) and 0.958 (BCC efficiency). In terms of his target value for improvement, he has 17.9 goals in the CCR model, and 17.8 goals in the BCC model, which is slightly lower than the CCR model. A. YANAGISAWA (No. 54) is BCC efficient, and has the same target value for improvement in the BCC model as the actual value.

Table 3-1 Efficiency and returns to scale: FW

No.	Player	CCR Eff.	BCC Eff.	Scale Eff.	Time	RTS
1	T.YAZIMA	1	1	1	1032	CRS
2	RENATO*	1	1	1	2168	CRS
3	QUIRINO	1	1	1	937	CRS
4	T.TAKAGI	1	1	1	1670	CRS
5	J.TANAKA	1	1	1	2022	CRS
6	K.KAWAMATA**	1	1	1	2503	CRS
7	N.ISHIHARA	1	1	1	2843	CRS
8	Choi Jung-Han	1	1	1	2418	CRS
9	GILSINHO	1	1	1	1434	CRS
10	M.MATSUHASHI	1	1	1	1246	CRS
11	G.OMAE	1	1	1	1207	CRS
12	M.SAITO*	1	1	1	2103	CRS
13	Y.OKUBO**	1	1	1	2967	CRS
14	Y.KOBAYASHI	1	1	1	1563	CRS
15	K.TAMADA	1	1	1	2419	CRS
16	Y.OSAKO**	1	1	1	2756	CRS
17	LUCAS Severino	1	1	1	2624	CRS
18	JUNINHO	1	1	1	2121	CRS
19	KENNEDY	1	1	1	2297	CRS
20	S.KIKUCHI	1	1	1	1844	CRS
21	T.TANAKA	1	1	1	1740	CRS
22	NOVAKOVIC	1	1	1	2173	CRS
23	R.NODA	1	1	1	1528	CRS
24	T.MINAMINO*	1	1	1	1540	CRS
25	K.SUGIMOTO	1	1	1	1428	CRS
26	WILSON	0.988	1	0.988	2545	DRS
27	S.ITO	0.977	1	0.977	1289	IRS
28	H.SATO*	0.974	1	0.974	2905	DRS
29	H.OKAMOTO	0.973	1	0.973	1398	IRS
30	G.HARAGUCHI	0.971	1	0.971	2553	DRS
31	Radončić	0.960	1	0.960	1257	IRS
32	K.WATANABE	0.952	0.958	0.994	2602	DRS
33	CHO Young Cheo	0.948	1	0.948	2673	DRS
34	M.KUDO	0.917	0.990	0.926	2885	DRS
35	K.HIRAMOTO	0.902	1	0.902	995	IRS
36	Y.TOYODA	0.879	1	0.879	2969	DRS
37	WELLINGTON	0.872	0.907	0.961	1287	IRS
38	K.YANO	0.865	1	0.865	983	IRS
39	K.TAKETOMI	0.863	1	0.863	1085	IRS
40	Y.HASEGAWA	0.862	1	0.862	1027	IRS
41	H.KANAZONO	0.860	0.874	0.983	1404	CRS
42	MARQUINHOS*	0.823	0.898	0.916	2824	CRS
43	DAVI	0.817	0.820	0.997	1858	CRS
44	CLEO	0.810	0.812	0.997	1833	IRS
45	HUGO	0.802	0.907	0.884	1152	CRS
46	EDNO	0.778	0.779	0.998	1835	CRS
47	D.TAKAMATSU	0.751	0.820	0.915	2047	DRS
48	Y.MORISHIMA	0.748	0.834	0.897	1402	IRS
49	A.KAWAMOTO	0.738	0.763	0.967	1171	CRS
50	R.MAEDA	0.735	0.826	0.889	2587	DRS
51	PATRIC	0.730	0.745	0.979	1569	CRS
52	K.IKEDA	0.719	0.824	0.872	2466	DRS
53	ZLATAN	0.715	0.725	0.985	2110	DRS
54	A.YANAGISAWA	0.712	1	0.712	1013	IRS
55	S.AKAMINE	0.712	0.780	0.913	2017	CRS
56	BARE	0.666	0.731	0.911	1436	IRS
57	S.KOROKI	0.661	0.749	0.882	2904	CRS
	Average	0.907	0.943	0.960	1906	
	S.D.	0.112	0.091	0.057	636	
	Max.	1	1	1	2969	
	Min.	0.661	0.725	0.712	937	

Remarks) * Recognized as outstanding players in 2013
** Recognized as the best eleven in 2013

Table 3-2 Efficiency and returns to scale: MF

No.	Player	CCR Eff.	BCC Eff	Scale Eff.	Time	RTS
1	Y.KAKITANI**	1	1	1	3018	CRS
2	MIKIC*	1	1	1	2256	CRS
3	S.FUJITA	1	1	1	950	CRS
4	JUNG Woo Young	1	1	1	967	CRS
5	Y.KASHIWAGI	1	1	1	2903	CRS
6	Kazu MORISAKI	1	1	1	2970	CRS
7	T.UMESAKI	1	1	1	1484	CRS
8	K.KANO	1	1	1	1120	CRS
9	N.KIKUCHI	1	1	1	1452	CRS
10	Y.OGAWA	1	1	1	2654	CRS
11	A.TANAKA	1	1	1	2935	CRS
12	Y.ABE*	1	1	1	2960	CRS
13	S.NAKAMURA**	1	1	1	2963	CRS
14	T.YONEMOTO	1	1	1	2764	CRS
15	LEO SILVA*	1	1	1	2812	CRS
16	S.YAMAGISHI	1	1	1	1206	CRS
17	Y.ENDO	1	1	1	1657	CRS
18	T.AOKI	1	1	1	3060	CRS
19	K.NAKATA	1	1	1	1866	CRS
20	T.HIRAKAWA	1	1	1	1906	CRS
21	KIM Min Woo	1	1	1	2932	CRS
22	RYANG Yong Gi	1	1	1	2549	CRS
23	K.NAKAMURA*	1	1	1	2532	CRS
24	J.INAMOTO	1	1	1	1758	CRS
25	MARQUINHOS P	1	1	1	1641	CRS
26	Y.MIKADO	1	1	1	2691	CRS
27	J.FUJIMOTO	1	1	1	2195	CRS
28	H.YAMADA	1	1	1	2698	CRS
29	T.AOYAMA*	1	1	1	2962	CRS
30	S.NARUOKA	1	1	1	2767	CRS
31	N.SUGAI	1	1	1	1857	CRS
32	T.AOKI	1	1	1	2440	CRS
33	H.YAMAGUCHI**	1	1	1	2926	CRS
34	T.EDAMURA	1	1	1	1048	CRS
35	Y.TAKAHASHI	1	1	1	2764	CRS
36	S.KOBAYASHI	1	1	1	2367	CRS
37	D.WATANABE	1	1	1	2849	CRS
38	T.NOZAWA	1	1	1	1553	CRS
39	R.HAYASAKA	1	1	1	1182	CRS
40	K.TAKAYAMA	1	1	1	2772	CRS
41	N.HANYU	1	1	1	1286	CRS
42	K.NAKAMACHI*	1	1	1	2903	CRS
43	DANILSON	1	1	1	2411	CRS
44	Y.KIMURA	1	1	1	1874	CRS
45	T.TAGUCHI	1	1	1	1665	CRS
46	K.NOBORIZATO	1	1	1	2517	CRS
47	Han Kook-Young	1	1	1	2634	CRS
48	M.YAMAMOTO	1	1	1	2820	CRS
49	R.KAJIKAWA	1	1	1	1166	CRS
50	M.OGASAWARA	0.999	1	0.999	2933	DRS
51	K.TOKITA	0.998	0.998	0.999	1434	IRS
52	H.YAMAMOTO	0.994	1	0.994	2554	DRS
53	K.MIZUNUMA	0.988	1	0.988	1808	IRS
54	CARLINHOS	0.987	1	0.987	989	IRS
55	H.TAMEDA	0.983	0.983	1.000	1786	DRS
56	S.TOMITA	0.980	0.980	1.000	2766	CRS
57	Y.MARUHASHI	0.977	1	0.977	2566	DRS
58	A.HASEGAWA	0.971	0.988	0.983	2797	DRS
59	R.NAGAKI	0.969	0.979	0.989	2887	DRS
60	H.OTANI	0.967	1	0.967	2770	DRS
61	Y.OTA	0.966	1	0.966	2563	DRS
62	H.ISHIGE	0.965	0.966	1.000	2131	CRS
63	S.HYODO	0.965	1	0.965	2821	DRS
64	Y.TAKAHAGI*	0.964	0.965	1.000	2744	CRS
65	Y.KAWAI	0.960	0.968	0.993	2543	DRS
66	S.KANAZAWA	0.955	0.965	0.990	2104	DRS
67	SIMPLICIO	0.949	0.951	0.999	2582	CRS
68	R.OSHIMA	0.946	1	0.946	955	IRS
69	H.TAKAHASHI	0.940	0.949	0.991	2618	DRS
70	K.HIGASHI	0.940	0.941	0.998	2594	CRS
71	K.SUZUKI	0.934	0.937	0.997	2289	CRS
72	N.FUJITA	0.933	1	0.933	2596	DRS
73	K.YAMAMOTO	0.932	0.943	0.988	1548	CRS
74	N.TAMURA	0.930	1	0.930	955	IRS
75	K.SUGIYAMA	0.927	0.998	0.929	2602	DRS
76	T.HONDA	0.921	1	0.921	1335	IRS
77	LEANDRO D	0.919	1	0.919	1031	IRS
78	T.MARUTANI	0.912	1	0.912	936	IRS
79	K.HOSAKA	0.907	0.998	0.909	1151	IRS
80	Y.KOBAYASHI	0.907	0.951	0.953	2621	DRS
81	JORGE WAGNER	0.901	0.903	0.998	1752	IRS
82	R.TAKEUCHI	0.899	0.914	0.984	1453	IRS
83	M.MIYAZAWA	0.885	0.924	0.958	1550	IRS
84	G.SHIBASAKI	0.880	0.935	0.941	2972	DRS
85	A.BARADA	0.877	0.962	0.912	1333	IRS
86	Y.KASHIWA	0.868	0.990	0.877	2934	DRS
87	T.UGAJIN	0.864	0.903	0.957	2337	DRS
88	N.SAKEMOTO	0.862	0.976	0.883	2544	DRS
89	K.MORIYA	0.860	1	0.860	902	IRS
90	H.NISHI	0.849	0.849	1.000	1570	CRS
91	R.KURISAWA	0.844	0.849	0.994	1938	CRS
92	T.MATSUSHITA	0.833	0.854	0.976	1487	IRS
93	RODRIGO MANCHA	0.831	0.853	0.974	2470	DRS
94	N.NAKAMURA	0.810	0.932	0.870	1289	IRS
95	T.MATSUURA	0.777	0.872	0.890	1318	IRS
	Average	0.962	0.981	0.981	2142	
	S.D.	0.054	0.038	0.034	687	
	Max.	1	1	1	3060	
	Min.	0.777	0.849	0.860	902	

Remarks) * Recognized as outstanding players in 2013
** Recognized as the best eleven in 2013

3.2. Super Efficiency

Tables 5-1 to **5-3** show super CCR efficiency results by position. **Table 5-1** shows super efficiency scores of CCR efficient FW players from higher to lower. Players No. 26 and after in **Table 5-1** are CCR inefficient players. Efficient frontier does not change regardless of inclusion or exclusion of the inefficient player himself; therefore, super efficiency and CCR efficiency scores become equal. **Table 5-2** and **5-3**

Table 3-3 Efficiency and returns to scale: DF

No.	Player	CCR Eff.	BCC Eff	Scale Eff	Time	RTS
1	HWANG Seok Ho	1	1	1	993	CRS
2	T.OGIHARA	1	1	1	2704	CRS
3	D.NASU**	1	1	1	2646	CRS
4	H.TANAKA	1	1	1	3003	CRS
5	K.OTA*	1	1	1	3033	CRS
6	DANIEL	1	1	1	1006	CRS
7	K.CHIBA	1	1	1	2992	CRS
8	S.ABE	1	1	1	2700	CRS
9	D.WATABE	1	1	1	1028	CRS
10	M.KAMEKAWA	1	1	1	1214	CRS
11	Y.KOMANO	1	1	1	3015	CRS
12	W.ENDO	1	1	1	1530	CRS
13	Kim Jin-Su	1	1	1	2778	CRS
14	K.HACHISUKA	1	1	1	1332	CRS
15	K.YAMAMURA	1	1	1	1903	CRS
16	T.MAKINO*	1	1	1	3060	CRS
17	R.NIWA	1	1	1	2948	CRS
18	D.SUZUKI	1	1	1	1953	CRS
19	T.SHIOTANI*	1	1	1	3049	CRS
20	Y.YASUKAWA	1	1	1	1922	CRS
21	K.TAKAGI	1	1	1	1782	CRS
22	Y.HIRAOKA	1	1	1	2670	CRS
23	W.SAKATA	1	1	1	2070	CRS
24	N.ISHIKAWA	1	1	1	2339	CRS
25	JECI	1	1	1	1710	CRS
26	T.MIYAZAKI	1	1	1	1964	CRS
27	M.KAKUDA	1	1	1	2295	CRS
28	LEE Kije	1	1	1	1418	CRS
29	S.KAMATA	1	1	1	1699	CRS
30	M.FUJITA	1	1	1	1102	CRS
31	Y.NAKAZAWA**	1	1	1	3009	CRS
32	MICHAEL JAMES	1	1	1	1169	CRS
33	N.AOYAMA	1	1	1	2602	CRS
34	T.MAENO	1	1	1	1233	CRS
35	H.WATANABE	1	1	1	1056	CRS
36	K.FUKUDA	1	1	1	2695	CRS
37	W.HASHIMOTO	1	1	1	1608	CRS
38	Marcus T.TANAKA	1	1	1	2350	CRS
39	M.WAKASA	1	1	1	1572	CRS
40	Y.KOBAYASHI	1	1	1	2839	CRS
41	R.MORIWAKI	1	1	1	2796	CRS
42	CHO Byung kuk	1	1	1	1784	CRS
43	T.KOBAYASHI	0.998	1	0.998	910	IRS
44	DUTRA*	0.997	1	0.997	2952	DRS
45	T.SHIMOHIRA	0.995	1	0.995	2625	IRS
46	K.OI	0.995	1	0.995	2912	DRS
47	H.MIZUMOTO*	0.994	1	0.994	3060	DRS
48	T.SIMAMURA	0.993	0.999	0.994	2013	DRS
49	Y.TANAKA	0.987	0.992	0.995	2637	CRS
50	J.KAMATA	0.982	0.990	0.992	2610	DRS
51	T.IMAI	0.975	0.976	1.000	1900	IRS
52	KIM Kun-Hoan	0.974	1	0.974	1630	IRS
53	S.SUGANUMA	0.960	1	0.960	1437	IRS
54	Y.FUJITA	0.959	0.973	0.986	2859	CRS
55	Y.IGAWA	0.956	1	0.956	1092	IRS
56	Y.TOKUNAGA	0.956	0.996	0.959	3060	CRS
57	YEO Sung Hae	0.955	0.969	0.986	2587	CRS
58	N.KAWAGUCHI	0.950	0.952	0.998	1821	IRS
59	S.SASAKI	0.949	1	0.949	2970	DRS
60	T.MASUKAWA	0.940	0.942	0.997	2425	CRS
61	K.KIKUCHI	0.938	1	0.938	2970	DRS
62	T.MURAMATSU	0.932	1	0.932	2942	DRS
63	K.FUJIMOTO	0.922	0.974	0.947	2464	DRS
64	T.YAMASHITA*	0.918	0.963	0.953	2223	DRS
65	D.NISHI	0.918	0.935	0.982	2380	CRS
66	T.SAKAI	0.916	0.998	0.919	1147	IRS
67	JNAG Hyun Soo	0.907	0.909	0.998	1946	CRS
68	M.INOHA	0.907	0.913	0.994	2055	CRS
69	Y.KURIHARA*	0.906	0.923	0.982	2790	DRS
70	Y.TSUCHIYA	0.904	0.909	0.994	1699	IRS
71	N.KONDO	0.902	0.955	0.945	2790	DRS
72	K.WATANABE	0.896	0.907	0.987	1694	IRS
73	K.KAGA	0.894	0.973	0.919	1372	IRS
74	T.MASUSHIMA	0.892	0.895	0.997	1907	DRS
75	M.MORISHIGE**	0.892	0.908	0.983	2970	CRS
76	H.ITO	0.892	0.949	0.940	1486	IRS
77	CALVIN JONG A PIN	0.885	0.988	0.896	2340	DRS
78	S.NAKAZAWA	0.869	1	0.869	1125	IRS
79	S.TAKAHASHI	0.865	0.875	0.989	2854	DRS
80	Y.SANETO	0.851	0.867	0.982	1679	IRS
81	T.MONIWA	0.843	0.856	0.985	1342	IRS
82	KIM Chang Soo	0.843	0.869	0.970	1624	IRS
83	Y.YOSHIDA	0.839	0.842	0.996	2155	IRS
84	S.TOMISAWA*	0.829	0.845	0.982	2502	CRS
85	K.ONO	0.770	0.805	0.957	2866	DRS
86	D.IWASE	0.747	0.748	0.999	1338	DRS
	Average	0.958	0.972	0.986	2148	
	S.D.	0.059	0.052	0.026	674	
	Max.	1	1	1	3060	
	Min.	0.747	0.748	0.869	910	

Remarks) * Recognized as outstanding players in 2013
** Recognized as the best eleven in 2013

show the results for MF and DF players.

Super efficiency can be calculated in both CCR and BCC models. As a reference, super efficiency scores utilizing the BCC model are also shown in **Tables 6-1** to **6-3**. QUIRINO (No. 38) has a super efficiency score of 1 in **Table 6-1**; however, his reference set players are not shown. This is because QUIRINO's time played is 937 minutes, the shortest among the 57 FW players, making it impossible to form a reference set for QUIRINO combining other players after excluding him. (His BCC efficiency score 1 is tentatively shown as the super efficiency score.) The same is the case for K. MORIYA and T. KOBAYASHI in **Tables 6-2** to **6-3**.

3.3. Parameters

Results of returns to scale are shown in the RTS column in **Table 3-1** to **3-3**. Constant returns to scale, increasing returns to scale, and decreasing returns to scale are indicated as CRS, IRS, and DRS respectively. Results for the reference set, reference frequency, and lambda value of players in the CCR model based on the concept of super efficiency are shown in **Tables 5-1** to **5-3**, and those in the BCC model are shown in **Tables 6-1** to **6-3** according to player position.

Table 4 Target values for improvement

No. Player	Present										Target(CCR)										Target(BCC)									
	Goals	Asists	Passes	Crosses	Dribbles	Tackles	Intercep tions	Clears	Blocks	Fouls	Goals	Asists	Passes	Crosses	Dribbles	Tackles	Intercep tions	Clears	Blocks	Fouls	Goals	Asists	Passes	Crosses	Dribbles	Tackles	Intercep tions	Clears	Blocks	Fouls
32 K.WATANABE	17	2	661	5	17	21	4	16	19	35	17.9	6.4	695	9.2	37.8	22.1	4.2	24.9	28.4	31.3	17.8	6.2	690	9.0	36.0	21.9	4.2	24.2	27.3	31.8
…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…
34 M.KUDO	19	4	517	10	27	16	1	9	30	39	20.7	7.6	739	13.3	39.2	17.5	3.9	29.3	32.7	31.7	19.2	4.0	760	10.1	54.4	16.2	2.6	23.7	32.8	38.2
…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…
37 WELLINGTON	3	0	279	3	6	25	1	23	19	53	3.4	2.2	320	3.4	9.3	28.7	4.3	26.4	25.3	27.1	3.3	2.4	308	3.4	12.8	27.6	3.8	26.7	24.3	35.3
…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…
42 MARQUINHOS*	16	3	529	11	30	25	4	5	20	79	19.4	6.6	643	13.4	38.3	30.4	4.9	31.3	28.7	45.0	17.8	6.5	818	12.2	53.1	27.8	4.45	13.7	33.2	48.2
…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…
53 ZLATAN	6	1	552	14	27	17	3	10	18	52	8.6	9.5	773	21.6	54.7	29.0	4.2	14.0	32.6	38.1	8.9	7.6	761	19.3	50.3	31.8	4.1	13.8	30.2	38.8
54 A.YANAGISAWA	3	1	195	0	1	8	0	0	8	18	4.2	2.7	317	6.1	12.0	11.2	2.2	9.4	14.4	8.4	3.0	1.0	195	0.0	1.0	8.0	0.0	0.0	8.0	18.0
55 S.AKAMINE	3	4	424	5	7	13	1	32	16	45	4.9	5.6	595	13.6	23.1	32.3	2.8	44.9	44.8	29.6	6.2	5.1	543	16.3	31.2	28.4	4.0	41.0	33.0	27.7
56 BARE	4	1	171	9	22	10	0	16	9	34	6.0	3.5	348	13.5	33.1	15.4	1.6	24.0	20.1	20.3	5.5	4.4	368	12.3	30.1	18.6	3.1	21.9	27.1	24.7
57 S.KOROKI	13	5	607	6	19	10	1	14	11	75	19.7	7.6	919	16.7	65.5	25.5	2.9	21.2	39.4	46.6	17.4	6.7	811	14.5	50.1	22.2	3.0	18.7	31.8	50.5

Remark) * Recognized as outstanding players in 2013

Table 5-1 Super CCR efficiency and reference sets: FW

No.	Player	Super CCR Eff.	Reference set (lambda)												Reference Frequency
1	T.YAZIMA	1.695	N.ISHIHARA	0.36											5
2	RENATO*	1.621	Y.OKUBO**	0.09	M.SAITO*	0.71	J.TANAKA	0.19							15
3	QUIRINO	1.482	K.KAWAMATA**	0.00	Choi Jung-Han	0.04	KENNEDY	0.10	Radončić	0.01	M.MATSUHASHI	0.48			22
4	T.TAKAGI	1.408	RENATO*	0.54	T.YAZIMA	0.49									3
5	J.TANAKA	1.395	NOVAKOVIC	0.09	RENATO*	0.49	T.TAKAGI	0.29	QUIRINO	0.29					18
	…	…	…	…	…	…	…	…	…	…					…
21	T.TANAKA	1.027	K.TAMADA	0.15	J.TANAKA	0.34	GILSINHO	0.33	T.YAZIMA	0.21					0
22	NOVAKOVIC	1.026	K.KAWAMATA**	0.41	Choi Jung-Han	0.02	J.TANAKA	0.20	M.MATSUHASHI	0.56					1
23	R.NODA	1.016	RENATO	0.12	M.SAITO*	0.23	GILSINHO	0.03	M.MATSUHASHI	0.03	T.YAZIMA	0.10	QUIRINO	0.65	0
24	T.MINAMINO*	1.009	K.TAMADA	0.00	RENATO	0.11	J.TANAKA	0.34	Y.KOBAYASHI	0.20	M.MATSUHASHI	0.24			0
25	K.SUGIMOTO	1.008	RENATO	0.28	M.MATSUHASHI	0.53	QUIRINO	0.17							0
26	WILSON	0.988	Y.OKUBO**	0.30	JUNINHO	0.28	J.TANAKA	0.21	T.TAKAGI	0.38					
27	S.ITO	0.977	J.TANAKA	0.51	M.MATSUHASHI	0.03	G.OMAE	0.01	QUIRINO	0.21					
28	H.SATO*	0.974	Y.OSAKO	0.10	K.KAWAMATA**	0.13	J.TANAKA	1.13							
29	H.OKAMOTO	0.973	N.ISHIHARA	0.02	J.TANAKA	0.39	Y.KOBAYASHI	0.17	T.YAZIMA	0.29					
30	G.HARAGUCHI	0.971	RENATO*	0.25	JUNINHO	0.12	J.TANAKA	0.44	T.TAKAGI	0.52					
	…	…	…	…	…	…	…	…	…	…					
42	MARQUINHOS*	0.823	Y.OKUBO**	0.10	N.ISHIHARA	0.27	Y.OSAKO**	0.06	K.KAWAMATA	0.46	RENATO*	0.20			
	…	…	…	…	…	…	…	…	…	…					
53	ZLATAN	0.715	RENATO*	0.50	J.TANAKA	0.24	GILSINHO	0.32	M.MATSUHASHI	0.07					
54	A.YANAGISAWA	0.712	K.TAMADA	0.10	J.TANAKA	0.19	Y.KOBAYASHI	0.25							
55	S.AKAMINE	0.712	RENATO*	0.12	J.TANAKA	0.28	M.MATSUHASH	0.83	QUIRINO	0.14					
56	BARE	0.666	K.KAWAMATA**	0.16	Choi Jung-Han	0.26	RENATO*	0.16	QUIRINO	0.07					
57	S.KOROKI	0.661	Y.OKUBO**	0.50	LUCAS Severino	0.11	RENATO*	0.42	QUIRINO	0.24					

Remarks) Correlation coefficient between super CCR efficiency and reference frequency: 0.630

* Recognized as outstanding players in 2013   ** Recognized as the best eleven in 2013

3.4. Correlation between Reference Frequency and Super Efficiency Scores

In terms of the correlation coefficients between reference frequency and super efficiency score in the CCR model, FW was 0.630, MF was 0.636, and DF was 0.326, as shown in **Tables 5-1** to **5-3**. In terms of the correlation coefficients between reference frequency and super efficiency score in the BCC model, FW was 0.414, MF was 0.574, and DF was 0.081, as is shown in **Tables 6-1** to **6-3**.

Table 5-2 Super CCR efficiency and reference sets: MF

No.	Player	Super CCR Eff.	Reference set (lambda)																Reference Frequency
1	Y.KAKITANI**	1.647	Y.ENDO	1.82															9
2	MIKIC*	1.630	LEO SILVA*	0.07	Y.ENDO	0.17	S.YAMAGISHI	1.49											20
3	S.FUJITA	1.325	N.KIKUCHI	0.01	S.YAMAGISHI	0.63	JUNG Woo Young	0.09	N.TAMURA	0.09									15
4	JUNG Woo Young	1.286	T.AOYAMA*	0.01	Y.MIKADO	0.08	T.TAGUCHI	0.32	T.UMESAKI	0.06	S.FUJITA	0.09							12
5	Y.KASHIWAGI	1.272	Y.TAKAHAGI	0.43	RYANG Yong Gi	0.00	J.FUJIMOTO	0.36	Y.ENDO	0.56									16
	...	...	...	...	...	...	...	...	...	...	...	...							...
45	T.TAGUCHI	1.016	Kazu MORISAKI	0.02	T.YONEMOTO	0.16	J.INAMOTO	0.07	N.KIKUCHI	0.09	JUNG Woo Young	0.84	S.FUJITA	0.12					0
46	K.NOBORIZATO	1.016	Kazu MORISAKI	0.20	T.YONEMOTO	0.02	Y.MIKADO	0.08	RYANG Yong Gi	0.05	MIKIC	0.28	K.NAKATA	0.34	N.HANYU	0.19			0
47	Han Kook-Young	1.012	Kazu MORISAKI	0.02	LEO SILVA*	0.75	T.YONEMOTO	0.03	N.KIKUCHI	0.17	JUNG Woo Young	0.13							2
48	M.YAMAMOTO	1.008	Kazu MORISAKI	0.37	S.NAKAMURA**	0.11	Y.ABE	0.01	RYANG Yong Gi	0.20	K.NAKATA	0.19	N.KIKUCHI	0.19	JUNG Woo Young	0.09	S.FUJITA	0.11	0
49	R.KAJIKAWA	1.006	Y.KAKITANI	0.09	Kazu MORISAKI	0.12	RYANG Yong Gi	0.00	T.HIRAKAWA	0.18	MARQUINHOS P	0.05	N.KIKUCHI	0.06					0
50	M.OGASAWARA	0.999	Kazu MORISAKI	0.03	Y.KASHIWAGI	0.41	T.YONEMOTO	0.12	RYANG Yong Gi	0.24	N.KIKUCHI	0.01	JUNG Woo Young	0.70					
51	K.TOKITA	0.998	Y.KAKITANI	0.01	LEO SILVA*	0.00	Y.TAKAHASHI	0.21	Y.OGAWA	0.04	N.KIKUCHI	0.04	JUNG Woo Young	0.59	S.FUJITA	0.11			
52	H.YAMAMOTO	0.994	T.YONEMOTO	0.12	Han Kook-Young	0.31	N.KIKUCHI	0.73	JUNG Woo Young	0.37	S.FUJITA	0.00							
53	K.MIZUNUMA	0.988	A.TANAKA	0.02	KIM Min Woo	0.10	S.NARUOKA	0.08	Y.OGAWA	0.31	MIKIC*	0.18							
54	CARLINHOS	0.987	Kazu MORISAKI	0.07	T.YONEMOTO	0.03	DANILSON	0.04	MIKIC*	0.09	J.INAMOTO	0.12	JUNG Woo Young	0.09	S.FUJITA	0.07			
	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...			
91	R.KURISAWA	0.844	Kazu MORISAKI	0.29	T.YONEMOTO	0.00	K.NAKATA	0.12	K.KANO	0.31	JUNG Woo Young	0.52							
92	T.MATSUSHITA	0.833	Kazu MORISAKI	0.01	S.NAKAMURA**	0.01	Y.ABE	0.11	KIM Min Woo	0.10	T.AOKI	0.20	K.NAKATA	0.02	K.KANO	0.16	S.FUJITA	0.10	
93	RODRIGO MANCHA	0.831	Kazu MORISAKI	0.04	T.YONEMOTO	0.13	Han Kook-Young	0.33	DANILSON	0.12	N.KIKUCHI	0.50	S.FUJITA	0.11					
94	N.NAKAMURA	0.810	Kazu MORISAKI	0.02	Y.ABE	0.16	LEO SILVA*	0.22	T.AOKI	0.02	N.KIKUCHI	0.07							
95	T.MATSUURA	0.777	S.NAKAMURA**	0.06	Y.KASHIWAGI	0.13	T.HIRAKAWA	0.28	Y.ENDO	0.13									

Remarks) Correlation coefficient between super CCR efficiency and reference frequency: 0.636

* Recognized as outstanding players in 2013 ** Recognized as the best eleven in 2013

4. Discussion

4.1. Comparison between CCR and BCC Models

The majority of players in all positions in this study were determined to be efficient, which is consistent with the results obtained by Hirotsu et al. (2012). The number of efficient players in the BCC model was greater than in the CCR model for all positions, which suggested that the BCC model yielded a more comprehensive picture of player characteristics. Although the number of efficient FW in the BCC model was approximately 50% more than that in the CCR model, the number of efficient MF and DF in the BCC model was low at approximately 30%, but more than that in CCR model. In both models, FW showed greater standard deviation and range of efficiency scores than MF and DF did. This suggested FW were superior in showing differences in the characteristics of individual players. The analysis of 2008 data regarding the CCR model revealed a similar tendency (Hirotsu et al., 2012), and it may be the general tendency seen in J1 and other leagues.

4.2. Scale Efficiency and Time Played

In terms of scale efficiency in this study, time played revealed the scale of player activities. Therefore, we can conclude that players whose scale efficiency was 1 had appropriate time played, and those whose scale efficiency was less than 1 did not have appropriate time played. Players from No. 1 to 25 in **Table 3-1** are thought to have appropriate time played because their scale efficiency is 1 and returns to scale is CRS. WILSON's (No. 26) BCC efficiency was 1 and returns to scale was DRS, which shows that he should have less than 2545 minutes of time played. Returns to scale for S. ITO (No. 27) was IRS, which shows that he should increase his time played from 1289 minutes. H. KANAZONO (NO. 41) was BCC inefficient; however, his returns to scale was CRS, which shows that his time played (1404 minutes) was appropriate. For BCC inefficient players, results of their returns to scale at the target value for improvement (reference point) on their BCC efficient frontier line are shown in **Table 3-1**. For example, H. KANAZONO is BCC inefficient

Table 5-3 Super CCR efficiency and reference sets: DF

No.	Player	Super CCR Eff.	Reference set (lambda)																		Reference Frequency
1	HWANG Seok Ho	1.729	T.MAKINO*	0.14	Y.KOMANO	0.13	D.NASU**	0.07													2
2	T.OGIHARA	1.700	K.OTA*	0.38	R.NIWA	0.29	R.MORIWAKI	0.25													11
3	D.NASU**	1.521	T.MAKINO*	0.55	M.KAKUDA	0.15	HWANG Seok Ho	0.62													13
4	H.TANAKA	1.489	K.OTA	0.04	W.HASHIMOTO	1.37	M.KAMEKAWA	0.56													4
5	K.OTA*	1.427	Y.KOMANO	0.79	T.OGIHARA	0.23	HWANG Seok Ho	0.02													3
	…	…	…	…	…	…	…	…													
39	M.WAKASA	1.016	Kim Jin-Su	0.00	D.NASU**	0.05	Y.YASUKAWA	0.74	HWANG Seok Ho	0.00											1
40	Y.KOBAYASHI	1.010	Y.KOMANO	0.40	S.ABE	0.25	T.MIYAZAKI	0.17	S.KAMATA	0.20	D.WATABE	0.28									0
41	R.MORIWAKI	1.010	T.MAKINO*	0.09	T.OGIHARA	0.28	D.NASU**	0.35	K.HACHISUKA	0.33	M.KAMEKAWA	0.33									0
42	CHO Byung kuk	1.003	T.SHIOTANI*	0.18	Kim Jin-Su	0.00	T.OGIHARA	0.15	Y.YASUKAWA	0.40	DANIEL	0.06									0
43	T.KOBAYASHI	0.998	N.AOYAMA	0.10	JECI	0.27	DANIEL	0.19													
44	DUTRA*	0.997	Y.KOMANO	0.18	K.CHIBA	0.03	S.ABE	0.35	N.ISHIKAWA	0.01	T.MIYAZAKI	0.31	S.KAMATA	0.02	M.KAMEKAWA	0.59					
45	T.SHIMOHIRA	0.995	T.SHIOTANI*	0.35	K.OTA*	0.09	Kim Jin-Su	0.46													
46	K.OI	0.995	T.SHIOTANI*	0.05	D.NASU**	0.03	W.SAKATA	0.34	JECI	0.19	D.WATABE	1.29	DANIEL	0.33							
47	H.MIZUMOTO*	0.994	K.CHIBA	0.22	S.ABE	0.06	S.KAMATA	0.23	W.ENDO	0.74	M.KAMEKAWA	0.58									
	…	…	…	…	…	…	…	…	…	…	…	…									
82	KIM Chang Soo	0.843	Y.KOMANO	0.06	H.TANAKA	0.07	R.NIWA	0.02	Kim Jin-Su	0.13	S.ABE	0.21	W.SAKATA	0.09	D.SUZUKI	0.01	K.YAMAMURA	0.00			
83	Y.YOSHIDA	0.839	T.SHIOTANI*	0.00	Y.KOMANO	0.16	H.TANAKA	0.12	R.NIWA	0.16	Kim Jin-Su	0.02	T.OGIHARA	0.05	S.ABE	0.18	D.NASU**	0.05	D.SUZUKI	0.01	
84	S.TOMISAWA*	0.829	T.SHIOTANI*	0.36	K.OTA*	0.01	K.CHIBA	0.02	T.OGIHARA	0.01	D.NASU**	0.24	W.ENDO	0.12	D.WATABE	0.47					
85	K.ONO	0.770	D.NASU**	0.21	N.ISHIKAWA	0.07	W.SAKATA	0.63	JECI	0.17	D.WATABE	0.53									
86	D.IWASE	0.747	T.OGIHARA	0.18	LEE Kije	0.00	MICHAEL JAMES	0.05	DANIEL	0.80											

Remarks) Correlation coefficient between super CCR efficiency and reference frequency: 0.326
* Recognized as outstanding players in 2013 ** Recognized as the best eleven in 2013

Table 6-1 Super BCC efficiency and reference sets: FW

No.	Player	Super BCC Eff.	Reference set (lambda)														Reference Frequency
1	T.YAZIMA	2.424	GILSINHO	0.08	G.OMAE	0.05	K.YANO	0.86									1
2	N.ISHIHARA	1.919	LUCAS Severino	0.11	KENNEDY	0.89											8
3	RENATO*	1.622	Y.OKUBO**	0.09	M.SAITO*	0.71	J.TANAKA	0.19									11
4	Choi Jung-Han	1.546	LUCAS Severino	0.63	JUNINHO	0.35	QUIRINO	0.02									7
5	Y.OKUBO**	1.413	M.KUDO	0.16	Y.OSAKO	0.76	RENATO*	0.09									10
	…	…	…	…	…	…	…	…									…
34	G.HARAGUCHI	1.018	Y.OKUBO**	0.35	N.ISHIHARA	0.01	CHO Young Cheol	0.15	Choi Jung-Han	0.28	JUNINHO	0.05	M.SAITO*	0.07	J.TANAKA	0.01	T.TAKAGI 0.08	0
35	WILSON	1.017	Y.OKUBO**	0.38	Choi Jung-Han	0.39	RENATO*	0.06	J.TANAKA	0.16							0
36	K.SUGIMOTO	1.010	RENATO*	0.26	GILSINHO	0.06	M.MATSUHASHI	0.47	QUIRINO	0.21							0
37	H.OKAMOTO	1.010	J.TANAKA	0.22	Y.KOBAYASHI	0.17	S.ITO	0.16	G.OMAE	0.09	T.YAZIMA	0.36					0
38	QUIRINO	1.000															12
39	M.KUDO	0.990	Y.OKUBO**	0.67	H.SATO*	0.00	Y.OSAKO	0.06	Choi Jung-Han	0.24	RENATO*	0.03					
40	K.WATANABE	0.958	Y.OKUBO**	0.29	H.SATO*	0.00	N.ISHIHARA	0.06	Y.OSAKO**	0.31	K.TAMADA	0.05	J.TANAKA	0.28			
41	HUGO	0.907	Y.OKUBO**	0.03	K.KAWAMATA**	0.01	G.OMAE	0.52	QUIRINO	0.44							
42	WELLINGTON	0.907	N.ISHIHARA	0.15	GILSINHO	0.09	K.HIRAMOTO	0.26	QUIRINO	0.50							
43	MARQUINHOS*	0.898	Y.OKUBO**	0.43	N.ISHIHARA	0.22	Y.OSAKO**	0.03	RENATO*	0.32							
44	H.KANAZONO	0.874	N.ISHIHARA	0.04	Y.OSAKO**	0.17	G.OMAE	0.35	QUIRINO	0.45							
	…	…	…	…	…	…	…	…	…	…							
53	A.KAWAMOTO	0.763	RENATO*	0.02	GILSINHO	0.40	M.MATSUHASHI	0.02	QUIRINO	0.55							
54	S.KOROKI	0.749	Y.OKUBO**	0.41	LUCAS Severino	0.21	RENATO*	0.25	J.TANAKA	0.13							
55	PATRIC	0.745	K.KAWAMATA	0.20	RENATO*	0.20	G.OMAE	0.20	T.YAZIMA	0.08	QUIRINO	0.31					
56	BARE	0.731	Choi Jung-Han	0.03	RENATO*	0.19	J.TANAKA	0.03	T.TAKAGI	0.19	S.ITO	0.15	QUIRINO	0.42			
57	ZLATAN	0.725	N.ISHIHARA	0.05	LUCAS Severino	0.13	K.TAMADA	0.06	RENATO*	0.46	J.TANAKA	0.06	GILSINHO	0.22			

Remarks) Correlation coefficient between super BCC efficiency and reference frequency: 0.414
* Recognized as outstanding players in 2013 ** Recognized as the best eleven in 2013

Table 6-2 Super BCC efficiency and reference sets: MF

No.	Player	Super BCC Eff.	Reference set (lambda)																Reference Frequency
1	S.FUJITA	2.819	S.YAMAGISHI	0.03	N.TAMURA	0.69	R.OSHIMA	0.01	K.MORIYA	0.26									9
2	Y.KAKITANI**	2.100	S.NAKAMURA**	1.00															5
3	MIKIC*	1.946	S.NAKAMURA**	0.45	S.KOBAYASHI	0.22	S.YAMAGISHI	0.33											12
4	JUNG Woo Young	1.784	T.EDAMURA	0.25	CARLINHOS	0.12	N.TAMURA	0.13	S.FUJITA	0.22	K.MORIYA	0.27							13
5	T.AOKI	1.703	Y.ABE	0.14	K.TAKAYAMA	0.09	H.YAMAMOTO	0.77											8
	...	...	...	...	...	...	...	...											...
60	K.MIZUNUMA	1.018	Y.OGAWA	0.36	MIKIC*	0.16	Y.ENDO	0.03	K.KANO	0.09	JUNG Woo Young	0.19	S.FUJITA	0.17					0
61	Y.KIMURA	1.018	T.YONEMOTO	0.01	RYANG Yong Gi	0.02	J.FUJIMOTO	0.65	K.NAKATA	0.07	K.KANO	0.01	JUNG Woo Young	0.19	S.FUJITA	0.06			1
62	Han Kook-Young	1.013	T.AOKI	0.00	Kazu MORISAKI	0.01	T.AOYAMA*	0.06	LEO SILVA*	0.74	H.YAMAMOTO	0.07	N.KIKUCHI	0.12	JUNG Woo Young	0.01			3
63	N.FUJITA	1.008	T.AOKI	0.01	Y.KASHIWAGI	0.22	H.OTANI	0.23	T.YONEMOTO	0.22	Y.TAKAHASHI	0.16	T.TAGUCHI	0.10	JUNG Woo Young	0.05			0
64	K.MORIYA	1.000																	1
65	K.SUGIYAMA	0.998	T.AOKI	0.19	Y.TAKAHASHI	0.51	Han Kook-Young	0.11	H.YAMAMOTO	0.05	N.KIKUCHI	0.15							
66	K.TOKITA	0.998	Y.KAKITANI**	0.01	H.YAMAGUCHI**	0.00	T.YONEMOTO	0.00	Y.TAKAHASHI	0.20	Y.OGAWA	0.03	N.KIKUCHI	0.04	JUNG Woo Young	0.60	S.FUJITA	0.112	
67	K.HOSAKA	0.998	Y.KAKITANI**	0.01	T.AOKI	0.05	N.KIKUCHI	0.08	R.KAJIKAWA	0.09	K.KANO	0.18	JUNG Woo Young	0.17	R.OSHIMA	0.41			
68	Y.KASHIWA	0.990	T.AOKI	0.03	S.NAKAMURA**	0.05	H.YAMAGUCHI**	0.28	Y.KASHIWAGI	0.10	LEO SILVA*	0.08	MIKIC*	0.45					
69	A.HASEGAWA	0.988	H.YAMAGUCHI**	0.05	Y.KASHIWAGI	0.82	M.YAMAMOTO	0.03	K.TAKAYAMA	0.04	N.KIKUCHI	0.07							
	...	...	...	...	...	...	...	...	...	...		...							
91	T.MATSUURA	0.872	T.HIRAKAWA	0.20	Y.ENDO	0.20	T.UMESAKI	0.00	S.YAMAGISHI	0.01	LEANDRO D	0.45	R.OSHIMA	0.14					
92	T.MATSUSHITA	0.854	Kazu MORISAKI	0.08	LEO SILVA*	0.01	T.AOKI	0.11	Y.ENDO	0.21	K.KANO	0.20	JUNG Woo Young	0.28	R.OSHIMA	0.01	S.FUJITA	0.092	
93	RODRIGO MANCHA	0.853	T.AOKI	0.02	Kazu MORISAKI	0.02	T.YONEMOTO	0.01	Y.TAKAHASHI	0.05	Han Kook-Young	0.31	H.YAMAMOTO	0.32	K.NOBORIZATO	0.09	K.NAKATA	0.19	
94	H.NISHI	0.849	H.YAMAGUCHI**	0.07	MIKIC*	0.12	MARQUINHOS P	0.16	N.HANYU	0.65									
95	R.KURISAWA	0.849	Kazu MORISAKI	0.25	KIM Min Woo	0.00	K.NAKAMACHI*	0.15	MIKIC*	0.00	K.NAKATA	0.19	K.KANO	0.06	JUNG Woo Young	0.35			

Remarks) Correlation coefficient between super BCC efficiency and reference frequency: 0.574
* Recognized as outstanding players in 2013 ** Recognized as the best eleven in 2013

Table 6-3 Super BCC efficiency and reference sets: DF

No.	DMU	Super BCC Eff.	Reference set (lambda)																				Reference Frequency
1	HWANG Seok Ho	6.138	M.FUJITA	0.19	DANIEL	0.49	T.KOBAYASHI	0.32															1
2	M.KAMEKAWA	1.773	R.NIWA	0.04	T.MAENO	0.44	H.WATANABE	0.52															4
3	T.OGIHARA	1.705	K.OTA*	0.37	R.NIWA	0.28	R.MORIWAKI	0.20	T.MAENO	0.14													9
4	D.NASU**	1.649	T.MAKINO*	0.46	M.KAKUDA	0.54																	9
5	Y.KOMANO	1.619	T.MAKINO*	0.55	K.OTA*	0.44	HWANG Seok Ho	0.02															10
	...	... ...	...	...	...	...	...	...															...
50	S.SUGANUMA	1.006	K.CHIBA	0.07	S.KAMATA	0.06	W.ENDO	0.39	M.KAMEKAWA	0.16	D.WATABE	0.32											0
51	Y.IGAWA	1.005	T.SHIOTANI*	0.01	K.CHIBA	0.03	H.WATANABE	0.16	DANIEL	0.80													0
52	KIM Kun-Hoan	1.003	K.CHIBA	0.01	N.ISHIKAWA	0.31	D.SUZUKI	0.02	W.ENDO	0.33	M.KAMEKAWA	0.01	D.WATABE	0.28	DANIEL	0.04							0
53	T.SHIMOHIRA	1.001	T.SHIOTANI*	0.32	K.OTA*	0.12	Kim Jin-Su	0.40	H.WATANABE	0.12	D.WATABE	0.04											0
54	T.KOBAYASHI	1.000																					4
55	T.SIMAMURA	0.999	Y.KOMANO	0.02	S.ABE	0.01	Y.HIRAOKA	0.08	N.AOYAMA	0.39	K.TAKAGI	0.09	JECI	0.18	DANIEL	0.23							
56	T.SAKAI	0.998	S.KAMATA	0.21	D.WATABE	0.62	T.KOBAYASHI	0.18															
57	Y.TOKUNAGA	0.996	T.SHIOTANI*	0.16	Y.KOMANO	0.30	Y.NAKAZAWA	0.34	S.ABE	0.19													
58	Y.TANAKA	0.992	K.OTA*	0.28	Kim Jin-Su	0.22	T.OGIHARA	0.27	Y.HIRAOKA	0.09	Y.YASUKAWA	0.07	D.WATABE	0.04	DANIEL	0.03							
59	J.KAMATA	0.990	T.SHIOTANI*	0.40	K.OI	0.02	Kim Jin-Su	0.38	W.SAKATA	0.06	DANIEL	0.13											
	...	... ...	...	...	...	...	...	...	...	...	...	...											
82	T.MONIWA	0.856	N.ISHIKAWA	0.16	W.SAKATA	0.14	D.WATABE	0.05	DANIEL	0.43	T.KOBAYASHI	0.22											
83	S.TOMISAWA*	0.845	T.SHIOTANI*	0.32	K.OTA*	0.10	Kim Jin-Su	0.05	T.OGIHARA	0.00	S.ABE	0.08	D.NASU**	0.25	D.WATABE	0.20							
84	Y.YOSHIDA	0.842	T.SHIOTANI*	0.03	Y.KOMANO	0.11	H.TANAKA	0.14	Kim Jin-Su	0.06	S.ABE	0.17	D.NASU**	0.05	D.SUZUKI	0.01	W.HASHIMOTO	0.04	T.MAENO	0.11	M.KAMEKAWA	0.28	
85	K.ONO	0.805	K.OI	0.55	Kim Jin-Su	0.01	S.ABE	0.03	Y.HIRAOKA	0.28	D.NASU**	0.14											
86	D.IWASE	0.748	T.OGIHARA	0.18	K.TAKAGI	0.02	W.ENDO	0.00	LEE Kije	0.02	DANIEL	0.78											

Remarks) Correlation coefficient between super BCC efficiency and reference frequency: 0.081
* Recognized as outstanding players in 2013 ** Recognized as the best eleven in 2013

and needs to increase efficiency to the target value for improvement. His returns to scale at the target value for improvement (reference point) are CRS, and his time played is appropriate. Returns to scale of K. WATANABE (No. 32) at his target value for improvement (reference point) is DRS, indicating that it is more efficient to decrease his time played. Application of the DEA method as described above allows us to discuss player characteristics from the standpoint of scale efficiency.

In this study, players did not increase meaningless passes or dribbles during games. We used data on frequency acquired while players were playing to win. Therefore, it is necessary to understand that target values for improvement were not set to increase meaningless plays for improvement in frequency, but simply to improve their play naturally during games.

4.3. Super Efficiency and Player Similarity

We examined super efficiency and player similarity according to individual players in reference to the super efficiency scores, reference sets, and lambda values shown in **Table 5-1**. For example, T. YAZIMA's super efficiency score is 1.695. This indicates that T. YAZIMA is 1.695 times from the CCR efficient frontier formed by 56 FW players excluding himself. His reference set is only N. ISHIHARA. RENATO's super efficiency score is 1.621, and his reference set is Y. OKUBO, M. SAITO, and J. TANAKA. **Table 3-1** shows the case without considering super efficiency. The efficiency scores of T. YAZIMA and RENATO and other efficient players are all 1, and there is no difference among them. However, the super efficiency concept could quantify the difference in player characteristics.

The correlation between super efficiency scores and reference sets can be examined in detail utilizing individual player data shown in **Table 7-1**. T. YAZIMA is characterized by interceptions. He made eight interceptions during 1032 minutes (time played). N. ISHIHARA made 13 interceptions in 2843 minutes, which was the second in interceptions per unit time only after T. YAZIMA. Multiplying 0.3630 (=1032/2843) by time played by N. ISHIHARA equals the same time played (1032 minutes) as T. YAZIMA. Multiplying 0.3630 by the number of interceptions made by N. ISHIHARA becomes 4.719 (=13×0.3630). Excluding T. YAZIMA, 1032 minutes (time played) and 4.719 interceptions, which were acquired by multiplying 0.3630 by those of N. ISHIHARA, are the efficient frontiers. T. YAZIMA's super efficiency in this case is 1.695 (=8/ 4.719).

RENATO is 1.621 times away from the efficient frontier acquired by combining Y. OKUBO, M. SAITO, and J. TANAKA excluding RENATO. Specifically, a virtual player with inputs and outputs acquired by multiplying the lambda values of three players, Y. OKUBO, M. SAITO, and J. TANAKA, (0.0929, 0.7135, and 0.1938) is the reference point on the efficient frontier for RENATO. Multiplying the time played by these three players with their lambda values provides the same amount of time played by RENATO (2967×0.0929+2103×0.7135+2022×0.1938 =2168). Calculation of number of goals with the same lambda values resulted in 7.401 (=26×0.0929+4×0.7135+11×0.1938). The actual number of goals made by RENATO was 12 and 12/ 7.401 = 1.621.

The same calculation for assists and dribbles for three players yielded 6.784 and 49.96, respectively; and the ratio with 11 and 81 by RENATO was 1.621 (=11/ 6.784=81/ 49.96). Excluding RENATO, Y. OKUBO, M. SAITO, and J. TANAKA form efficient frontiers for goals, assists, and dribbles; and RENATO is 1.621 times away from the reference point on the frontier, and his super efficiency score is 1.621. On the other hand, RENATO is also characterized as 1.621 times better than the virtual player, which is the combination of the three players, in goals, assists, and dribbles. According to **Table 7-1**, distance regarding goals, assists, and dribbles from the origin to the reference point in a three-dimensional space is $\sqrt{7.401^2 + 6.784^2 + 49.96^2} = 50.96$, and distance from the origin to RENATO is $\sqrt{12^2 + 11^2 + 81^2} = 82.62$. The ratio of both, which is 1.621 (=82.62/50.96), is the super efficiency score.

T. YAZIMA and RENATO have different reference sets, and the factors that form efficient frontiers are also different. Therefore, the difference between these two players is extreme. Based on T. YAZIMA and RENATO, shown in **Table 7-1**, we can identify similarity in the characteristics of efficient players (here, similarity between T. YAZIMA and N. ISHIHARA or similarity among RENATO, Y. OKUBO, M. SAITO, and J. TANAKA) utilizing reference sets and lambda values .

It is also possible, to a certain extent, to determine the degree to which the characteristics of efficient players evaluated by DEA model match the actual state, and at which input and output the efficiency

Table 7-1 Input and output values and reference point

	Time	Goals	Asists	Passes	Crosses	Dribbles	Tackles	Interceptions	Clears	Blocks	Fouls	Lambda
T.YAZIMA	**1032**	3	1	162	0	6	7	**8**	9	18	15	
N.ISHIHARA	2843	10	5	739	5	16	67	13	29	40	56	0.3630
Ref.Point	**1032**	3.630	1.815	268.3	1.815	5.808	24.32	**4.719**	10.53	14.52	20.33	
RENATO	**2168**	**12**	**11**	866	29	**81**	27	2	3	33	40	
Y.OKUBO	2967	26	4	842	4	52	8	2	12	31	37	0.0929
M.SAITO	2103	4	6	594	20	57	40	6	7	42	33	0.7135
J.TANAKA	2022	11	11	610	19	23	13	5	24	30	15	0.1938
Ref.Point	**2168**	**7.401**	**6.784**	620.3	18.32	**49.96**	31.80	5.436	10.76	38.66	29.89	

Table 7-2 Virtual output values

Player	Goals	Asists	Passes	Crosses	Dribbles	Tackles	Interceptions	Clears	Blocks	Fouls
T.YAZIMA							**1.00**			
N.ISHIHARA	0.18					**0.58**	0.24			
RENATO	0.18	0.25			**0.57**					
Y.OKUBO	**0.70**		0.30							
M.SAITO				0.01	0.23	0.23	0.12		**0.24**	0.17
J.TANAKA		**0.44**					0.05	0.10		0.41

score 1 is acquired utilizing each value in the weighted output $\sum_{r=1}^{s} u_r y_{rj_o}$ (Hirotsu et al., 2012). **Table 7-2** shows the data for T. YAZIMA and RENATO. These values show the ratio of the contribution of each input and output to bring the efficiency score to 1, which makes it possible to identify player characteristics and correlation with actual frequency.

As is shown in **Table 7-2**, for example, T YAZIMA only excels in interceptions with a super efficiency score of 1.695. This proves that he was evaluated by the number of interceptions per time played, as was mentioned above. Ranking second in interceptions, N. ISHIHARA's goals, tackles and interceptions are 0.18, 0.58, and 0.24, respectively, indicating that he is efficient, and made many tackles. In fact, N. ISHIHARA was ranked top among FW players at 67 tackles for the year.

When RENATO's goals, assists, and dribbles against time played were 0.18, 0.25, and 0.57, respectively, his characteristics were very distinctive. RENATO was characterized by frequency exceeding the virtual player who made the same number of goals Y. OKUBO scored, assists that J. TANAKA made, and dribbles M. SAITO made. In addition, RENATO was ranked top among FW players at 11 assists and 81 dribbles for the year, which proves that RENATO was evaluated because of these facts. As shown in **Table 2**, RENATO is ranked top among FW players for passes and crosses per time played; however, he is followed by others at a very narrow margin. Therefore, his passes and crosses were not items that differentiate his characteristics. Y. OKUBO is ranked top at 26 goals, and J. TANAKA is ranked top at 11 assists (the same as RENATO).

Looking at the best eleven players and those who were recognized as outstanding players in 2013 (J-League, 2014) from the standpoint of a comprehensive evaluation for the year, these players are also BCC efficient in **Table 3-1**, **3-2**, and **3-3**. However, MARQUINHOS (No. 42, FW), Y. TAKAHAGI (No. 64, MF), and T. YAMASHITA (No. 64, DF) are BCC inefficient although they were recognized as outstanding players. This is because their characteristics were overshadowed by other players' performance. For example, MARQUINHOS was inferior to the virtual player combining Y. OKUBO, N. ISHIHARA, Y. OSAKO, and RENATO as shown in **Table 6-1**. MARQUINHOS (weighted output for goals : 0.60) was characterized by the number of goals and as a desirable FW. BBC model analysis did not evaluate MARQUINHOS as a distinctive player because there were other excellent players in terms of the number of goals. In terms of goals, MARQUINHOS's target value for improvement was to increase approximately two more goals, as shown in **Table 4**.

We can see a difference between CCR and BCC model evaluations under the concept of super efficiency through a comparison of **Table 5-1**, **5-2**, and **5-3** with **Table 6-1**, **6-2**, and **6-3**. Individually, while N. ISHIHARA is included in the reference set based on the CCR model for T. YAZIMA, three other players were the reference set based on the BBC model. This shows that players included in the reference set for an individual player differ significantly between CCR and BCC models. This is because BCC model evaluation is a relative evaluation among players whose scale (here, time played) is close, which results in the inclusion of players whose efficiency scale is close in the reference set. On the other hand, the CCR model does not impose restrictions on the scale, which allows a relative evaluation among players regardless of their scale. This results in the formation of a significantly different reference set. Time played by GILSINHO, G. OMAE, and K. YANO, who were included in the reference set of T. YAZIMA in the BCC model, were 1434, 1207, and 983 minutes, respectively, and relatively close to T. YAZIMA's performance (1032 minutes). However, time played by N. ISHIHARA, included in the reference set based on the CCR model is 2843 minutes, and his efficiency scale becomes significantly different.

4.4. Correlation between Reference Frequency and Super Efficiency

Reference frequency and super efficiency score show characteristics of efficient players. The correlation between the two was 0.326 – 0.636 in the CCR model. This shows that super efficiency and reference frequency do not necessarily have a strong correlation and that these two factors are evaluations from slightly different viewpoints. As was described in 2. 3, while high reference frequency identifies differences in the characteristics of efficient players and whether the player has comprehensive or peculiar characteristics, super efficiency provides a relative indication of how far the player is from other similar players. As a result, they show that they do not necessarily have a strong correlation

Correlation in the BCC model was also weak at 0.574 or lower. Correlation in DF was 0.081, which was extremely low. This was due to the fact that the super efficiency of WANG SEOK HO (No. 1) in **Table 6-3** is extremely high. Excluding HWANG SEOK HO, the correlation is 0.591.

Comparison of correlation between reference frequency and super efficiency in the CCR and BCC models, the BCC model was always low. This may have been because the BCC model has more flexibility in evaluation, and many players were evaluated as efficient. However, excluding HWANG SEOK HO (DF), the correlation was 0.591, which was higher than that in the CCR model (0.34). Therefore, we need to examine and discuss this more in detail.

We concluded that evaluation using both CCR and BCC models helped us to more broadly understand player characteristics. We could also acquire scale efficiency, which suggested whether a player needs to increase or decrease time played. Furthermore, the concept of super efficiency allowed us to quantify the difference in characteristics of players, and to identify similarity in characteristics between efficient players utilizing reference set and lambda value. Reference frequency and super efficiency scores do not necessarily show strong correlation, but they evaluate player characteristics from slightly different viewpoints. This study suggested that evaluation utilizing the BCC model and concept of super efficiency is more useful than utilizing the CCR model only.

5. Conclusion

We explained the evaluation of J1 player characteristics developed from the analysis established by Hirotsu et al. (2012) utilizing DEA. We calculated efficiency, scale efficiency, and super efficiency according to player position and classified players into three groups, "increasing returns to scale," "decreasing returns to scale," and "constant returns to scale," to examine whether the time played by each player was appropriate from the standpoint of utilizing their characteristics. We also quantified the characteristics of efficient players and similarity between players utilizing super efficiency and lambda value. We showed that evaluations by super efficiency and reference frequency in reference sets were slightly different utilizing correlation coefficient.

Utilizing DEA analysis in this study, we could quantify characteristics of individual players as well as evaluate various abilities of players from the standpoint of efficiency, and expand the potential for discovering various player abilities.

In this study, we applied the DEA method to analyze data on inputs and outputs based on the performance results of the year to understand player performance, which is difficult to analyze by simply examining data. Because it is data based, a methodological limitation of this study is that it cannot analyze information that cannot be seen by the data. The interpretation of the results of the analysis is left to the judgment of coaches.

Inputs and outputs can be changed freely according to requirement, which allows researchers to discover other player characteristics through changes in input and output items, such as adding number of games played and analyzing inputs and outputs according to player position. We will further expand this study to make this analysis useful to coaches. We also hope that more analyses on soccer players utilizing DEA will be conducted, which will promote research on the usefulness and validity of evaluations.

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